EN200

LAB #6 PRELAB

RIGHTING ARM B - TRANSVERSE SHIFTS IN G

Instructions

1. The first part of this lab consists of a prelab that covers the theory that will be examined experimentally in this lab.

2. It is to be handed to your instructor at the beginning of the lab period.

3. If you can, answer the questions without referring to your notes. Only refer to them when you are confused or fail to understand a concept. This will greatly improve your understanding of the concepts the lab is designed to reinforce. Remember you will have no notes during quizzes, tests and exams.

4. By conscientiously completing this prelab, you will have a thorough understanding of what the lab is trying to show. Your lab performance will be maximized.

5. **All work must be shown on your lab for proper credit.** This means that you must show generalized equations, substitution of numbers, units and final answers. Engineering is communication. Work that is neat and shows logical progression is easier to grade.

Student Information

Name: ____________________________

Section: __________

Date: ____________

Aim:

- Reinforce the students' understanding of righting arm theory.
- Demonstrate the effect of a transverse shift in the center of gravity on ship stability.
- Show how the change in stability due to a transverse shift in G can be predicted.

Part 1: Prelab

Apparatus:

1. The apparatus used in this lab is exactly the same as for lab 5, the stern view is shown in Figure 1. The one major difference in this lab is that the curve of intact statical stability is being constructed for the model with weights moved to the starboard post, this will give the model a center of gravity starboard of the centerline.

2. The wire connected to the perimeter of the circular disc and passing to the force gauge will be used again to apply an external force to the model called F_{wire}. The magnitude of F_{wire} being measured on the gauge. The angle of heel (ϕ) will be monitored using the protractor, line and weight mechanism.

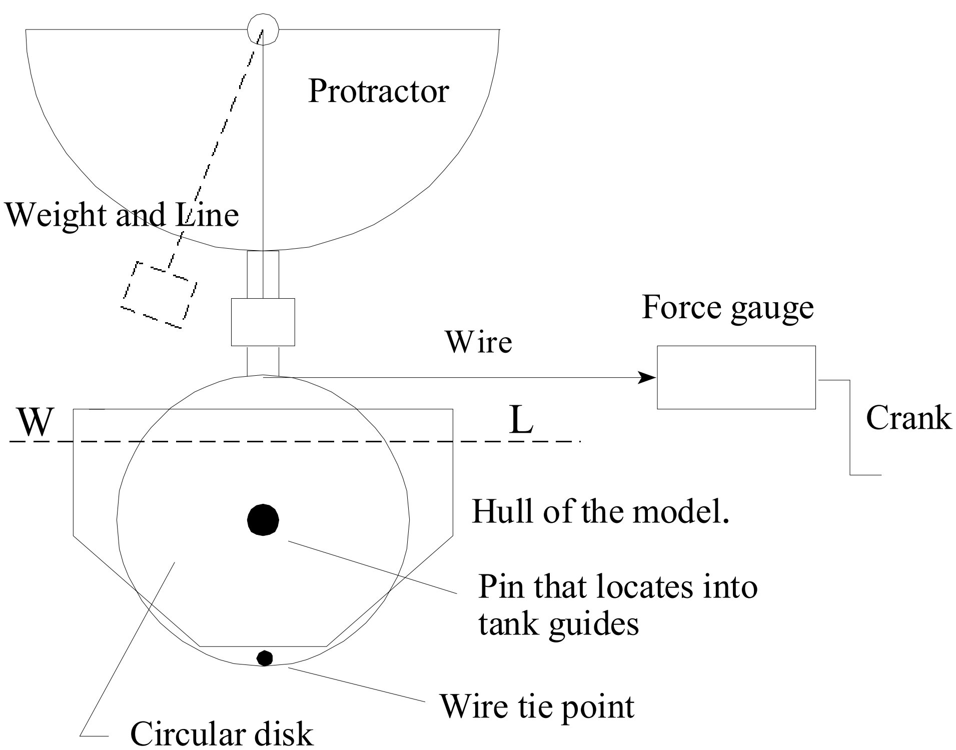

Figure 1 – Stern view of apparatus

Theory

3. You will recall from lab 5 that the force in the wire (F_{wire}) and its equal and opposite partner (F_{pin}) supply the external couple that heels the ship. The magnitude of this couple is given by the following:

$$External\ Couple = F_{wire}R_{disc}$$

4. This external couple is countered by the internal couple being created by the mis-alignment of G and B. The magnitude of the internal couple is given by the following:

$$Internal\ Couple = \Delta_S\overline{\mathrm{GZ}}$$

5. Figure 2 represents the model being listed with the forces and couples mentioned above. Since the model is at static equilibrium when heeled, the external and internal couple must cancel each other out. In the box below give the equation that links the 2 couples and solve this to find an expression for the righting arm GZ.

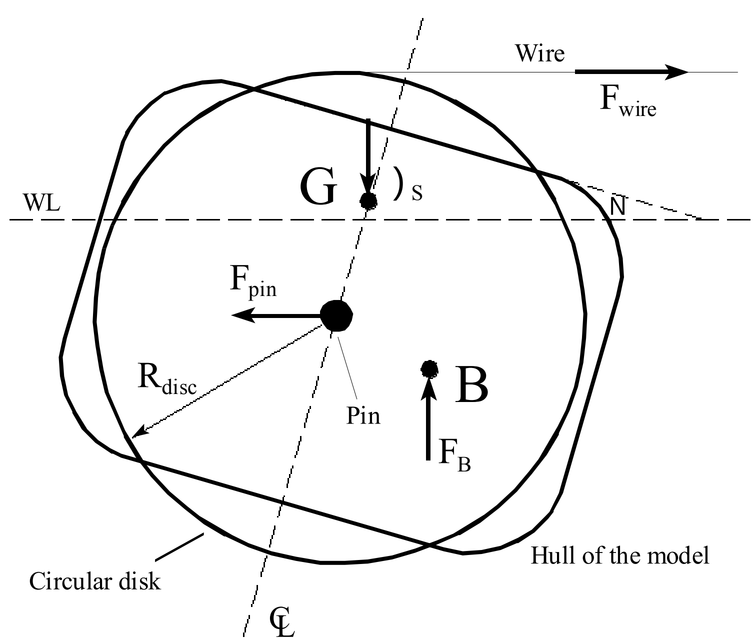

Figure 2 – Simplified View of Heeling Model

6. In this lab, the center of gravity of the ship will be shifted transversely. The effect this has upon the curve of intact statical stability will be measured. It should be possible to predict this effect by an analysis of the heeling ship shown in Figure 3.

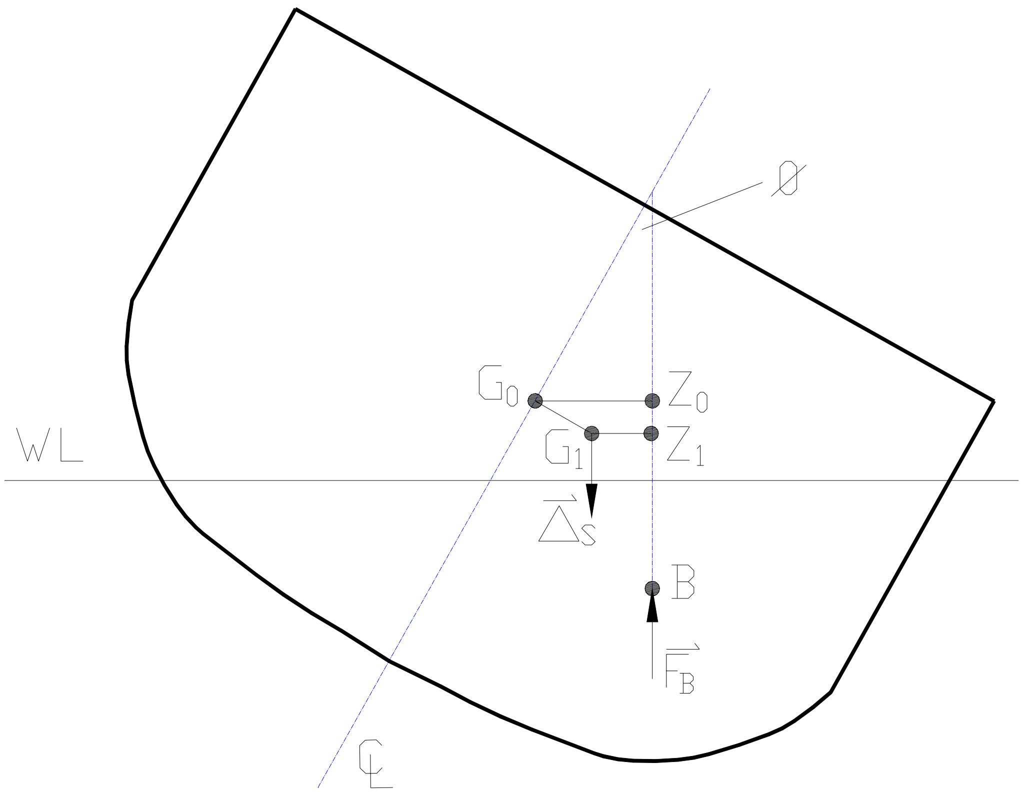

Figure 3 – The Heeling Ship with a Transverse Shift in the Center of Gravity

7. In the box below, use Figure 3 to derive an equation for the new righting arm (G_1Z_1) after a transverse shift in the center of gravity from G_0 to G_1. Your equation should include the old righting arm (G_0Z_0) and the angle of heel (ϕ).

IMPORTANT!!

8. Before you can start the lab, you will need the information you acquired from the Righting Arm A (Lab 5) concerning the 27-B-1 model you are working with.

   Remember you must use the same 27-B-1 model for all your EN200 laboratories

   a. **Find the KG_{normal} you calculated from Lab 5 and insert this data in the appropriate cell at the bottom of page 8 of this lab.**

   b. **Plot the curve of intact statical stability data for the ship in its normally loaded condition you found in lab 5 on the axis on page 13. This will be required to compare the stability of the model in its normally loaded and transversely loaded conditions.**

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EN200

LAB 6: RIGHTING ARM B - TRANSVERSE SHIFTS IN G

Instructions

1. This lab is **conducted in the hydrolab** on the lab deck of Rickover Hall.

2. You will need to **bring this lab to the lab period**. You must also have recorded the KG_{normal} at the bottom of page 8 and plotted the curve of intact statical stability for the model in its normally loaded condition on the axis on page 13. All these quantities were calculated and measured in the Righting Arm A Lab, Lab 5.

3. The lab is to be performed in small groups of 2 or 3 but **each member of the lab group is to submit their own work**. You can ask questions and discuss the content of the lab, but the submitted work must be your own.

4. Another way the learning experience of the lab can be destroyed is by failing to **follow the stages of the lab consecutively**. The lab follows a logical thought pattern, jumping ahead without doing the intervening theory questions will limit your understanding.

5. **All work must be shown on your lab for proper credit.** This means that you must show generalized equations, substitution of numbers, units and final answers. Engineering is communication. Other people should be able to understand your work.

6. **This lab is to be submitted at the end of the lab period**.

Student Information:

Name:___________________________ Date:_____________________

1st Partner________________________ 2nd Partner____________________________

3rd Partner:_______________________ 4th Partner:____________________________

Part 2: Procedure

Apparatus

1. Before beginning the experiment, ensure the 27-B-1 model number corresponds with the number on the solid floored tank, the protractor and the tank. **This must be the same as the model used in labs 4 and 5.**

   27-B-1 model number = ______________________

Light-ship Condition

2. The first step is to ensure the model 27-B-1 is in its light-ship condition. This is achieved by the following:

   a. Ensure all detachable weights are off the model (1.5 lb weight, 4 x 0.15 lb weights, and protractor device.

   b. Ensure there is no loose water within the central compartment.

   c. **Ensure the solid floored tank with its flooded side down is securely installed in the center compartment**.

Normally Loaded Condition

3. The model must then be loaded to achieve its normally loaded condition. All quantities concerning the model can then have the suffix 'normal' once it has been loaded. The load consists of the following.

   a. Protractor device mounted on the weather deck.

   b. One 1.5 lb weight mounted on the center post.

   c. 4 x 0.15 lb weights mounted on top of the 1.5 lb weight on the center post.

4. Use the scale or otherwise to find the model's displacement in its normally loaded condition (Δ_{normal}) and place this value in the table below. **This should be the same value as calculated in the previous lab, KG_{normal} should have been inserted in the table already.**

Normally Loaded Condition	Δ_{normal} (lb)		KG_{normal} (in)	

Transversely Loaded Condition.

5. Before the model can be moved to its transversely loaded condition, it must be floated in the tank and any initial list corrected with the transverse weights. Perform the following steps.

    a. Make sure all the weights and protractor are secure on the model. Also ensure the hatch cover is correctly fastened. You are going to capsize the model, you don't want water entering the central compartment.

    b. Float the model in its normally loaded condition so that its pins are inserted in the grooves on the tank.

    c. Connect the wire from the circular disc to the force gauge making sure it passes around the groove in the circumference of the plate.

    d. With the wire in a slack condition (F_{wire} = 0 lb), make sure the model is floating upright. Alter the locations of the transverse weights to achieve this.

    e. Zero the force gauge and make sure the red switch is in its central (neutral) position.

6. Now the model can be moved into its transversely loaded condition. Move the1.5 lb weight from the center post to the starboard post, leaving the 0.15 lb weights on the center post. All quantities concerning the model can then have the suffix 'trans' once these weights have been shifted.

7. Record the initial angle of list below. **Remember starboard angles are positive, port angles are negative.**

Initial Angle of List (Degrees)	

8. A quantity you will need in further calculation is the distance the weights have been shifted (t). This corresponds to the distance between the starboard and center posts. Record this distance below.

Distance of transverse weight shift (inches)	

Construction of the Curve of Intact Statical Stability for Transversely Loaded 27-B-1 Model.

9. The construction of the curve of intact statical stability can now begin. Perform the following steps.

    a. Record the angle of list corresponding to zero force in the wire.

    b. Heel the model using the crank connected to the force gauge.

    c. Record the force F_{wire} at 5 degree increments and place the data in the table on page 11.

    d. When you have heeled the boat to capsize in one direction, turn the boat round and heel it to capsize on the other.

    e. When completing the data table, remember that **by convention, port distances and heels are negative.**

10. To calculate the righting arm, GZ at each angle of heel, you will recall that in the prelab you derived the following equation.

$$\overline{GZ}(in) = \frac{F_{wire}(lb)\, R_{disc}(in)}{\Delta_s(lb)}$$

Since there has been only a shift in weights on board the model, there has been no alteration in the models displacement. Consequently:

$$\Delta_S = \Delta_{normal} = \Delta_{trans}$$

You recorded Δ_{normal} at the bottom of page 8.

R_{disc}, the radius of the disc, is 3 in.

Port Measurements		
Angle of Heel ϕ (Degrees)	**Force in the Wire F_{wire} (lb)**	**Righting Arm GZ (in)**

Starboard Measurements		
Angle of Heel ϕ (Degrees)	**Force in the Wire F_{wire} (lb)**	**Righting Arm GZ (in)**

11. Plot this data on the axis on page 13, the curve of intact statical stability for the model in its normally loaded condition should be plotted already. You are encouraged to utilize the capabilities of a spreadsheet program to compute righting arms and plot data.

Remember:

label your axis correctly
title your plot correctly
port measurements and angles are negative

12. From the 2 curves on page 13, complete the following table.

Heeling to Port		
Condition	Normally Loaded	Transversely Loaded
Range of Stability (Degrees)		
Maximum Righting Arm (in)		
Angle of Max RA (Degrees)		

Heeling to Starboard		
Condition	Normally Loaded	Transversely Loaded
Range of Stability (Degrees)		
Maximum Righting Arm (in)		
Angle of Max RA (Degrees)		

13. What deduction can you make from the table about the overall stability of a ship when heeling in the direction of a transverse weight shift?______________________________

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Why? ____

14. What deduction can you make from the table about the overall stability of a ship when heeling away from the direction of a transverse weight shift?________________________

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Why? ____

15. To show you understand the geometry of the heeling conditions sketch the model in the following conditions and heeling angles. Your sketches should include the center of buoyancy (B), center of gravity (G), the displacement (Δ_{normal} or Δ_{trans}), the buoyant force (F_B), the angle of heel (ϕ), the waterline and the righting arm (GZ) if applicable.

Normally Loaded Condition	**Transversely Loaded Condition**
Zero degrees of heel	Initial heeling angle
Angle of GZ_{max} to starboard	Angle of GZ_{max} to starboard
60 degrees of heel to port	60 degrees of heel to port

Normally Loaded Condition		Transversely Loaded Condition
Capsize angle to port		Capsize angle to starboard

Calculation of the Effects on Stability of a Transverse Shift in G.

19. The effects on stability of a transverse shift in G can be determined provided the amount it has moved is known. In the box below, give the generalized equation for the calculation of a new TCG after a weight shift, addition or removal.

In this particular case you will recall that the movement in G was created by the shift of the 1.5 lb weight ($W_{1.5}$) from the center post to the starboard post, a distance (t). This distance was recorded on page 9.

Rewrite the equation above in terms of these quantities, substitute their values and solve for the TCG of the model in its transversely loaded condition (TCG_{trans}).
Hint: TCG_{normal} can be assumed zero as the model had zero initial list in its normally loaded condition.

20. In the prelab you proved that a transverse shift in G would reduce the righting arm (GZ) at an angle of heel (ϕ) by the following equation.

$$\overline{G_1 Z_1} = \overline{G_0 Z_0} - \overline{G_0 G_1}\ Cos\,\phi$$

Show that you understand the derivation of this equation by completing the diagram of the heeling ship at Figure 6. The diagram should include the center of buoyancy (B), the new and old centers of gravity (G_0 & G_1), the new and old righting arms (G_0Z_0 & G_1Z_1), the angle of heel (ϕ), the displacement (Δ_S) and the buoyant force (F_B).

Also clearly show the cosine correction term.

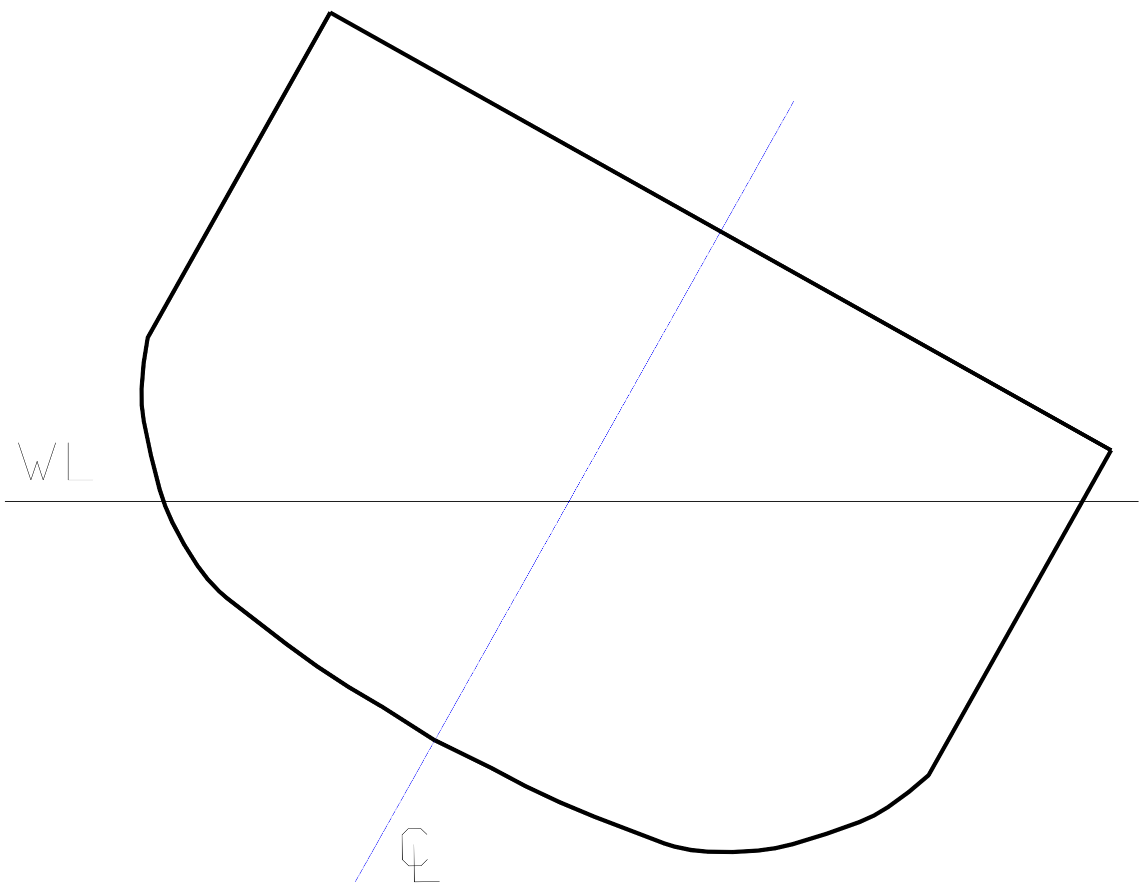

Figure 4 – The Heeling Ship with a Transverse Shift in G

21. Use the values for TCG_{normal} and TCG_{trans} to calculate the magnitude of the line segment G_0G_1.

22. Use this value and the cosine correction equation to complete the table below.

Angle of Heel ϕ (Degrees)	Normally Loaded Righting Arm G_0Z_0 (in)	Cosine Correction Term $G_0G_1 Cos\varphi$ (in)	Calculated Corrected Righting Arm G_1Z_1 (in)
0			
15			
30			
45			

23. Plot the calculated data on the curve of intact statical stability on page 13.

24. Comment upon any differences between the calculated data points for the corrected righting arm with those found experimentally. ___________________________________

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25. Has this proved or disproved the accuracy of the cosine correction? __________________

Why? ____

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